Year Two Progress Report for NASA Grant NNG06GH15G

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Summary:

This work is designed to explore the efficacy of alternative computational hardware to the challenges of cosmological data analysis and machine learning. During our second year, we have built upon our previous work to target, develop, and benchmark new platforms, as well as to expand the range of algorithms being tested.

First, we have continued our analysis into the efficacy of FPGA-based hardware to the computational challenges in calculating the two-point correlation analysis. Second, we have extended this analysis to the calculation of the angular power spectrum. Third, we have developed a tree-based, fast, parallelized two-point correlation code for NCSA supercomputer systems and have leveraged this new implementation to provide additional performance gains on our brute-force, computational accelerator implementations. Finally, we have extended these implementations to leverage NVidia CUDA GPU systems.

Review:

In 2007, SRC-6 code development work was mostly focused on improving the previously developed implementation of the two-point angular correlation code. Two major advancements were made: reimplementation of the core computations using fixed-point arithmetic that resulted in a 70% performance improvement of the kernel, and an addition of a workload distribution framework that resulted in a 9% performance improvement of the overall application. This work was awarded the 2007 SRC Award for Excellence in Reconfigurable Computing. An initial port of this code to the NVidia GPU produced a nearly 100 times speed-up in the distance calculations, but the single-precision floating point nature of the current generation of GPU systems prevents the practical application of this work. This is expected to change with the next-generation NVidia GPU cards.

We also evaluated a kd-tree based two-point angular correlation implementation on the SRC-6, which was found to be generally not suitable in its current form. The reason

being is a prevalent control flow nature of the tree-based implementation which encapsulates sparsely distributed compute kernels that operate only on a small subset of data at a time. Restructuring the code in a manner that would use the tree-based range search as a pre-processor and would accumulate the point pairs for a later test on an FPGA-based system is an alternative approach that needs to be investigated further. This work will leverage the fast tree-based parallel code being developed by graduate student Josh Dolence and PI Brunner. This code is nearly complete, runs on extremely large datasets (tens of millions of data points) across hundreds of computational nodes, and will be made publicly available once fully tested later this year.

The angular power spectrum code was further refined and tested, successfully reproducing Tegmark's 2001 results for power spectrum of SDSS stripe 10. Given the differences in algorithm and basic data set, this was an important step to verify our overall code base. This code was ported to the SRC-6 system, which resulted in a decrease in performance due to the memory-bandwidth limitations of the SRC-6 platform. This work was subsequently ported to the NVidia GPU, which produced block speed-ups of approximately 350 times a standalone CPU.

Future work will continue to improve these basic algorithm implementation on alternative hardware, and also the extension of these implementations to utilize FPGA and GPU clusters within a common code framework. These clusters are already in place within the Innovative System Laboratory at NCSA.

Synergistic Activities:

PI Brunner and Co-PI Kindratenko have leveraged this funded work to partner with others on the Illinois campus to work towards the development of a center for the application of computational accelerator technologies. This effort has resulted in a funded NSF SGER award to Kindratenko and Brunner, and our participation in an NSF EIC pre-proposal (PI Wen-mei Hwu, ECE/CSL University of Illinois). We also are planning to submit an NSF CDI proposal later this year to extend this funded work on the use of computational accelerators to Astronomical applications.

Both Kindratenko (Chair) and Brunner serve on the program committee for the 2008 Reconfigurable Systems Summer Institute. Kindratenko also served as the Workshop co-Chair for the First International Workshop on High-Performance Reconfigurable Computing Technology and Applications (HPRCTA'07), and he was the organizer for the panel on (Super)computing on FPGAs, GPUs, Cell and Other Exotic Architectures: Challenges and Opportunities, both of which were held during the 2007 IEEE/ACM Supercomputing conference in Reno Nevada.

Publications:

V. Kindratenko, C. Steffen, R. Brunner, Accelerating Scientific Applications with Reconfigurable Computing: Getting Started, Computing in Science and Engineering, vol. 9, no. 5, pp. 70-77, 2007 (paper)

V. Kindratenko, R. Brunner, A. Myers, Dynamic load-balancing on multi-FPGA systems: a case study, In Proc. 3rd Annual Reconfigurable Systems Summer Institute - RSSI'07, 2007 (paper)

R. Brunner, V. Kindratenko, and A. Myers, Developing and Deploying Advanced Algorithms to Novel Supercomputing Hardware, In Proc. NASA Science Technology Conference - NSTC'07, 2007 (paper)

V. Kindratenko, R. Brunner, A. Myers, Mitrion-C Application Development on SGI Altix 350/RC100, In Proc. IEEE Symposium on Field-Programmable Custom Computing Machines - FCCM'07, 2007 (paper)

Presentations:

T. El-Ghazawi, D. Buell, K. Gaj, V. Kindratenko, Reconfigurable Supercomputing tutorial, IEEE/ACM Supercomputing, November 12, 1997, Reno NV.

V. Kindratenko, High Performance Computing on FPGAs: challenges and opportunities, Panel on Key Challenges presented by next generation hardware systems, Key Challenges in Modeling and Simulation Fall Creek Falls conference, September 2007, Nashville TN.

V. Kindratenko, Dynamic load-balancing on multi-FPGA systems: a case study, Reconfigurable Systems Summer Institute - RSSI'07, July 18-21, 2007, Urbana, IL.

V. Kindratenko, Accelerating Cosmology Applications: from 80 MFLOPS to 8 GFLOPS in 4 steps, SRC's User Meeting, July 17, 2007, Urbana, IL.

V. Kindratenko, Accelerating Scientific Applications with Reconfigurable Computing, Dept. of Computer and Information Sciences, University of Alabama at Birmingham, June 25, 2007, Birmingham, AL.

V. Kindratenko, Developing and Deploying Advanced Algorithms to Novel Supercomputing Hardware, NASA Science Technology Conference - NSTC'07, June 19-21, 2007, Adelphi, MD.

V. Kindratenko, Mitrion-C Application Development on SGI Altix 350/RC100, IEEE Symposium on Field-Programmable Custom Computing Machines - FCCM'07, April 23-25, 2007, Napa, CA.

Brett Hayes, Angular Power Spectrum Estimation using High Performance Reconfigurable Computing, Reconfigurable Systems Summer Institute - RSSI'07, July 18-21, 2007, Urbana, IL.